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William F. Caton
Secretary
Federal Communications Commission
1919 M Street, N.W.
Washington, D.C. 20554

August 4, 1994

Dear Mr. Caton:

Transmitted herewith for filing are 1 original and 4 copies of a **Petition for Rule-Making** (to allow use of slant wire radiators), prepared and filed on behalf of **Milstar Broadcasting Corp.**

A courtesy copy has been simultaneously sent to Jim Burtle of the FCC's AM Branch, with reference to Milstar's pending application for an AM construction permit (ARN-9000702AE).

If there are any problems or questions, please contact me; and, thanks.

Cordially,

Barry Skidelsky

BdS:hp
att.
cc: M. Wilson (Milstar)
J. Burtle (FCC/AM Branch)

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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

PETITION FOR RULE-MAKING

(to allow use of slant wire radiators)

Milstar Broadcasting Corp. ("Milstar"), Commission licensee of WXCT (AM) in Hamden, Connecticut, by counsel, hereby submits a Petition For Rule-making, as follows.

As the Engineering Statement attached hereto and made a part hereof elaborates, Milstar proposes that the Commission modify its rules and policy to allow use of slant wire radiators by AM broadcast stations [1].

As the <u>NOI</u> (at 4) notes: "Many of the current rules and policies governing AM directional antenna systems were adopted as part of the Commission's former Standards of Good Engineering Practice in 1939."

Since then, significant regulatory, environmental, technological and economic changes have occurred, which warrant grant of this Petition.

The regulatory and economic changes are self-evident and reflected in the Commission's general approach to AM improvement. The relevant environmental changes relate principally to urban and suburban growth, which has limited land use as AM transmitter sites.

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1 Relatedly, Milstar filed Reply Comments in response to the Commission's Notice of Inquiry ("<u>NOI</u>") in MM Docket No. 93-177 (regarding AM Directional Antenna Performance Verification). Incorporation by reference is requested.

Relevant technological changes are also known to the Commission; but, attention is drawn specifically to the following. Applicable current FCC rules and regulations are based on the assumption that the radiator is <u>always</u> vertical; but, such assumption is no longer valid.

Alternative arrays such as parasitic and fed slant wires have been developed, which have proven to be successful in practice in other countries. For example, the July 1994 issue of BE Radio magazine reports use of such an array at XEWB, a 50 kw AM radio station in Mexico.

Milstar believes that the majority of AM radio stations in the United States who might use slant wire arrays would likely operate with far less power; and, that current technology, as evidenced by the XEWB installation, provides strong assurances of ability to adjust and maintain slant wire arrays.

Although current Commission rules apparently permit the use of vertical parasitic arrays, Commission policy or practice has been to reject their use. <u>The Commission should specifically allow the use of parasitic and fed slant wire radiators or arrays</u>.

Allowing the flexible use of slant wire arrays, in part, will enable stations to prevent or reduce interference to other stations, as well as suppress signal strength in areas where it is not needed (e.g.: over bodies of water).

Moreover, use of slant wire arrays will permit existing coverage to be improved or night-time coverage added, while requiring less land and money than does adding one or more towers.

Conservation of land and capital are surely also in the public interest. In sum, adequate technological justification and strong public interest considerations warrant grant of this Petition.

Respectfully,

MILSTAR BROADCASTING CORP.

by Barry Skidelsky, Esq.
655 Madison Avenue
19th floor
New York, NY 10021

August 4, 1994

ENGINEERING STATEMENT
PREPARED ON BEHALF OF
MILSTAR BROADCASTING CORP.
IN SUPPORT OF A
PETITION FOR RULEMAKING

In the Matter of

Modification to the FCC Rules
Sections 73.150 and 73.160
To Allow Use of Slant Wire Radiators

SUMMARY

This engineering statement has been prepared on behalf of **Milstar Broadcasting Corp. ("Milstar")**, licensee of AM station WXCT, Hamden, Connecticut. As a broadcast licensee, owner of a directional antenna facility on 1220 kHz and applicant for improved facilities, **Milstar** asks the Commission to modify the above referenced Rules, by making minor changes as proposed infra, which would provide standard broadcast stations added flexibility regarding their antenna systems. The minor rule changes proposed herein will allow many AM stations to implement directional antenna systems using existing or fewer towers, yet which meet the required coverage and protection criteria. The proposed rule changes will also facilitate the design and installation of simpler, less expensive, directional antenna systems, such as parasitic arrays. **Milstar's** proposal would also allow the diplexing or combining of two or more AM stations on the same tower, at reduced cost.

Technical aspects of this proposal are described in detail, as follows.

PARASITIC ARRAYS

Parasitic arrays differ from the traditional directional antenna systems licensed by the FCC, in that not all of the towers are directly fed with power from the transmitter through a transmission line. In a parasitic array, at least one tower is directly fed, and one or more non-fed towers are used. The desired radiation pattern is achieved by the use of a shunt reactance and by selecting height, physical separation and orientation with respect to the tower(s) being fed.

Directional arrays employing parasitic elements can be less expensive to build and maintain than an antenna system where all towers are fed. In particular, a directional pattern can be achieved by attaching a slant wire to an existing nondirectional tower at very little expense. This type of antenna would allow many existing stations to add viable nighttime service at low cost. In addition, slant wire parasitic arrays could be easily implemented in the expanded band as an example of the "simple directional antenna systems" described in paragraph 107 of the Report and Order in MM Docket No. 87-267, "Review of the Technical Assignment Criteria for the AM Broadcast Service", released October 25, 1991 ("Review of AM Technical Criteria").

Technically, parasitic arrays are antenna systems where one tower is fed and the remaining towers shape the antenna pattern by virtue of their height and physical relationship to the tower being fed. They have been in use for decades. George H. Brown wrote about parasitic arrays in the Proceedings of the Institute of Radio Engineers ("IRE"), Vol. 25, No. 1, January 1937. Brown described the design of single parasitic reflector arrays at great length in this article. ***Figure 1***, attached, is a copy of the computed directional antenna patterns found in the IRE article. In the conclusion of his paper, Brown stated:

> "In the preceding discussion, we have treated the cases of both driven and parasitic arrays. Where possible, the results have been tested by comparison with experimental results.
>
> The field and circuit conditions are treated for the case of multi-element driven arrays. For a given current ratio and phase relation, the effective impedance of each antenna and the total radiated power, as well as the power radiated by each antenna, are readily found. The radiation pattern of the array is easily calculated. These arrays are often used to protect the service areas of other stations operating on the same frequency.
>
> In the case of a single parasitic reflector, it is found that the mysterious something that is supposed to happen when the spacing is one-quarter wave length fails to materialize. Closer spacings are found to be desirable in both the transmitting and receiving case. It is found that the parasitic antenna functions equally well as a director or a reflector."

Today, parasitic arrays are built and used on a regular basis in all parts of the world including Canada, Mexico and the Caribbean. Just one example is CHUC, 1450 kHz, Cobourg, Ontario, Canada which uses a three tower array employing a parasitic element.

Although current FCC Rules do not specifically prohibit parasitic radiators, the practice of the AM Branch of the Mass Media Bureau is, and has been, not to allow the use of parasitic arrays. **Milstar** requests that this policy, and the FCC Rules, be modified to specifically allow parasitic arrays.

It is believed that parasitic arrays have not been encouraged by the AM Branch, to date, due to historical uncertainty as to pattern prediction or adjustment. However, as the Commission notes in paragraph 5 of the NPRM, in MM Docket No. 93-177 (AM Directional Antenna Performance Verification), "several sophisticated antenna array modeling programs are now available for use on computers which can predict patterns for very complex combinations of power and phase." Currently available programs based on the Numerical Electromagnetics Code, Method of Moments, do, in fact, allow very accurate prediction of parasitic array operating characteristics and performance. Moreover, the use of a variable reactance to ground at the base of a parasitic element provides control or adjustment of the radiation pattern, so that construction permit limitations may be met and interference to other stations avoided. Thus, the FCC's historical aversion to parasitic arrays need not continue, and the use of parasitic arrays, such as slant wire radiators, should be permitted.

SLANT WIRE RADIATORS

Interest in using slant wire radiators has been re-kindled, in part, by Grant W. Bingeman, of Continental Electronics/Varian, Dallas, Texas, who presented a paper at the 41st Annual Broadcast Engineering Conference Proceedings, NAB, 1987, entitled "An Economical Directional Antenna For AM Stations". A copy of a portion of this paper is attached as *Appendix 1* to **Milstar's** Petition. In his paper, Bingeman described a parasitic directional antenna made up of a vertical guyed tower and one guy wire configured as the parasitic element.

Mr. Bingeman has found interest in his design in the international broadcasting community. The July issue of *Broadcast Engineering Radio* describes an existing installation of a parasitic slant wire array designed and tested by Mr. Bingeman. It is expected that publishing this technology in a widely read periodical will further increase demand for this type of antenna system. Affiant has already found a great level of interest in the slant wire antenna concept among owners of broadcast stations with single AM towers.

In practice, a sloping radiator can also be a cable attached to a tower with its length and orientation set to satisfy a specific protection requirement. Such slant wire can either be fed (as in a traditional directional array) or used as a parasitic element (with pattern shape adjustments being made with a variable reactance between the sloping wire and ground). The Commission should specifically allow the use of parasitic and fed slant wire radiators, whether vertical or not.

FCC RULES SECTIONS 73.150 AND 73.160

A principal impediment to use of slant wire arrays is that the formulas found in Sections 73.150 and 73.160 of the FCC Rules and Regulations are based on a simplified assumption that the radiator is always vertical. If one wishes to compute the radiation pattern for a slanting or sloping radiator, the current formulas are insufficient. To solve this problem, **Milstar** proposes to modify Sections 73.150 and 73.160 of the FCC Rules to include an elegant set of mathematical formulas developed by the Commission's own former Chief Engineer, Harry Fine, in his paper dated June 30, 1951, "Radiation From Grounded Slant Antennas." Mr. Fine's paper is labeled and attached as ***Appendix 2*** to this Petition.

BENEFITS TO THE PUBLIC AND BROADCAST COMMUNITY

Milstar believes that the public and broadcast community would benefit should the Commission allow the use of slant wire arrays.

Slant wire arrays offer particular advantages in a number of situations. For example, they give an existing broadcaster with a single nondirectional tower the ability to add a modest directional antenna pattern. This would be particularly beneficial for stations wishing to gain added nighttime service, who have a deep nighttime protection requirement.

In addition, stations wishing to move to the Expanded Band could employ a sloping radiator on their existing tower with a diplexer. This would minimize the expense of the diplexer circuitry and allow for the implementation of a simple directional antenna pattern in the expanded band if desired.

Also, parasitic slant wire arrays, in particular, are less expensive to build and maintain than fed arrays, in part because feedlines and power distribution and phasing circuitry are not required. Lastly, zoning, site or land use restrictions may be of lesser impact.

FCC RULE CHANGES, INTERNATIONAL CONSIDERATIONS

It is **Milstar's** belief that no changes to the Rules are required for vertical parasitic arrays. The FCC's computer routine "Radiat" already supports the use of vertical parasitic arrays and reflects the formulas found in Sections 73.150 and 73.160 of the Commission's Rules. Nonetheless, an express recognition of their permitted use is in the public interest.

Non-vertical (i.e., slant wire) parasitic arrays would require modification to the formulas found in Sections 73.150 and 73.160, as suggested by the 1951 paper written by Harry Fine, then Chief Engineer, Federal Communications Commission Technical Research Division, T.R.R. Report No. 1.2.5 entitled "Radiation From Grounded Slant Antennas". **Milstar** recommends the elegant formulas within this paper as the basis for modification to Sections 73.150 and 73.160 of the Rules. This paper appears in *Appendix 2*.

CONCLUSION

Milstar believes that it is timely and prudent to modify the FCC Rules to allow the use of parasitic and fed slant wire radiators or arrays. Failure to allow use of the broadest spectrum of radiator types disserves the public interest and fails to give broadcasters the flexibility necessary to deal with today's zoning and other land use restrictions. If allowed, **Milstar** intends to implement a parasitic slant wire array which would allow for improved coverage without the need for new tower construction or property additions.

The foregoing was prepared on behalf of **Milstar Broadcasting Corp.** by Clarence M. Beverage of *Communications Technologies, Inc.*, Marlton, New Jersey, whose qualifications are a matter of record with the Federal Communications Commission. The statements herein are true and correct of his own knowledge, except such statements made on information and belief, and as to these statements he believes them to be true and correct.

By ______________________

Clarence M. Beverage
for Communications Technologies, Inc.
Marlton, New Jersey

SUBSCRIBED AND SWORN TO before me,

this 4th day of August, 1994,

Esther G Sperbeck, NOTARY PUBLIC

ESTHER G. SPERBECK
NOTARY PUBLIC OF NEW JERSEY
MY COMMISSION EXPIRES OCT 15, 1997

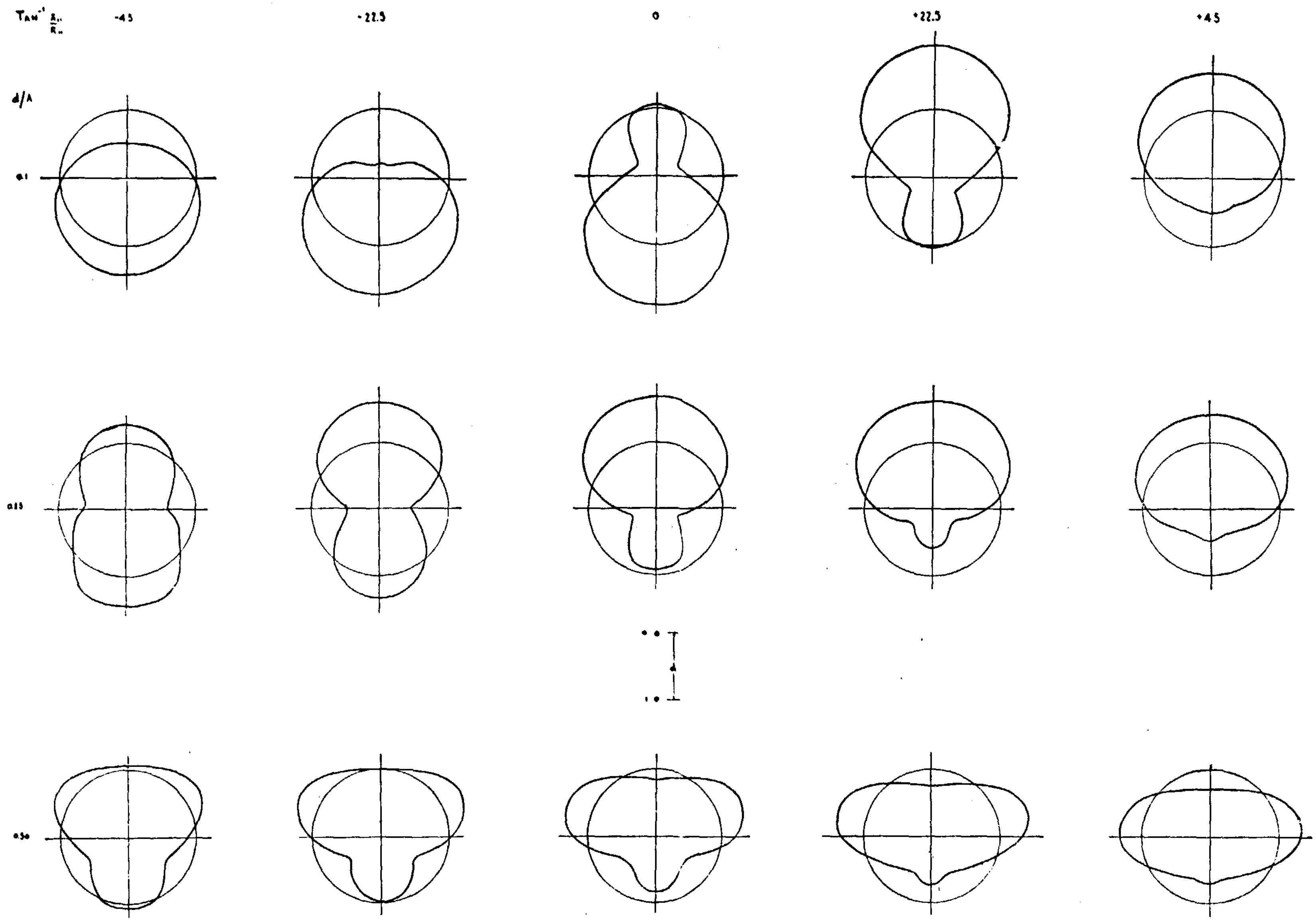


Fig. 28—The horizontal radiation patterns of an antenna and a single reflector, for a number of spacings and tuning conditions.

FIGURE 1

From Proceedings
of the IRE, Vol. 25,
No. 1, January 1937

AN ECONOMICAL DIRECTIONAL ANTENNA FOR AM STATIONS

GRANT W. BINGEMAN

CONTINENTAL ELECTRONICS / VARIAN

An existing non-directional broadcast site can be modified to produce a directional gain of three dB, equivalent to doubling transmitter power in the direction of maximum gain, without adding another tower. This is accomplished by using one of the guy wires as a parasitic element. All insulators on the selected top-level guy are shorted except the top and bottom ones. This guy wire can then be tuned at its base.

If the tower is near 90 degrees in height, the guy requires a capacitive tuning reactance for both reflector and director performance. More capacitive reactance is required to produce a director. When the guy is tuned as a director, driver resistance is lower, and bandwidth is narrower. Thus best overall results are usually obtained by tuning the guy as a reflector when the full length of the guy wire is in circuit.

Ordinarily one might expect the reflector to require an inductive reactance at its base, since an inductor makes a wire look longer, and a capacitor makes a wire look shorter. Normally a reflector is physically longer than the driven element, and a director is shorter. Keep in mind that a guy wire is typically 12 to 15 percent longer than its tower projection. Thus a full-length top-level guy wire on a quarter-wave tower may behave as a reflector when shorted at its base, depending on how much of the tower top is cantilevered. If the tower were only 70 degrees tall, then an inductive reactance would indeed be required to make one of its top-level guys perform as a reflector.

This raises the possibility of tuning the guy by adjusting its active length. That is, why not short the bottom guy insulator to ground, then short just enough of the upper insulators to produce the desired pattern? This eliminates the need for a tuning reactance alltogether. Figure 1 shows two of the many patterns which can be obtained in this way when the tower is a quarter wave tall. Bandwidth is also best when no tuning reactance is used.

It may sometimes be convenient to drive the guy-wire, and tune the tower. Since the tower is not as long as the guy, it requires somewhat less capacitive tuning reactance at its base. Comparing Figures 2 and 3, where identical tower and guy dimensions are used, one can see that similar gains are obtainable. However, the input impedance of the driven tower case (Figure 3) is about half that of the driven guy case (Figure 2). This is not too important, as the bandwidths of the two configurations are comparable. However, one case may be easier to match to the transmission line impedance. As expected with this close element spacing, bandwidth is rather narrow compared to a non-directional tower alone (see table of impedances in Figure 3).

Figure 4 compares the vertical patterns of a 250 foot non-directional tower to that of the driven-tower, tuned-guy arrangement of Figure 3. Note the significant increase in high-angle radiation contributed by the parasitic guy wire. This may affect the contours of the night-time fading zone, but that is very dependent on the specific ground conductivity of the area in question.

Allow me to point out that very-high-angle radiation is not likely to be refracted back to earth by the ionosphere, and even if it were, the return signal would be too weak to affect communication in the primary service area. For example, Figure 3 shows a field of 109 mV/m at a mile straight up. The E layer of the ionosphere is about 60 miles up at night, making a round trip of about 120 miles. Even if the straight-up signal were perfectly reflected, the returning signal would be less than one mV/m at the ground.

A horizontally polarized field component exists for elevation angles outside of the tower/guy or the azimuth planes (Figure 5). Note that both the E_ϕ and the E_θ spherical-coordinate field components are parallel to the azimuth plane when the elevation angle is 90 degrees (straight up). One's sense of up, down, and sideways can become a bit disoriented in a spherical coordinate system where V-pol and H-pol are relative to the observer, not to the azimuth plane.

At any rate, calculation of the fading zone is a relatively straightforward process, and should be part of any application of this hot-guy concept of antenna design.

If desired, tuning can be accomplished with an inductor at the base of the parasitic element, rather than a capacitor, if that element is made short enough. Figure 6 employs 156 feet of hot guy wire, which can be tuned as either a director or a reflector. Note that the transition between director and reflector operation is rapid. From the standpoints of pattern bandwidth and stability, it would be best to tune the parasitic tower to the conservative side of maximum gain, away from the crossover point.

If we define the crossover point between director and reflector operation as the point where equal forward and reverse gains are obtained, some interesting correlations can be observed. Referring to Figure 7, one can see that the relative phase of the tower currents passes through 180 degrees at the crossover point. This is useful knowledge when an antenna monitor is part of the system. Another obvious feature is the peaking of base currents at crossover. This can be a useful tuning aid when an antenna monitor is not available, but an RF ammeter is at hand.

As expected, driving-point impedance changes most rapidly when tuning approaches the crossover point (Figure 8 shows the tower base impedance for the configuration of Figures 6 and 7). Since the tower currents peak at crossover, the base resistance reaches a minimum value. If an impedance bridge is available, crossover can be determined by tuning for minimum feedpoint resistance.

Some special considerations are created when one chooses to use one or more of the guy wires as array elements. First, the voltage stresses across the remaining guy insulators are usually increased, and the voltage gradient on the guy wire is also increased. Of course, the currents in the hot guys are increased. These parameters are easily calculated with general moment-method algorithms, and do need to be taken into account during the design process.

Second, some consideration must be given to improving the ground system near the base of the hot guy wire. Since the guy is acting as a second tower, its ground system should be similar to that of a normal tower. However, in light of the saving in real-estate and tower costs, this is a minor annoyance.

Third, in some installations, the bottom guy insulator may not be very close to the ground. In this case, a drop wire will have to be added if the guy is to be tuned at the base with a reactance.

Although I have not specifically shown any tall tower appplications, there is no reason parasitic guys cannot produce similar results for any height of tower.

All data were obtained using the moment method of antenna analysis.

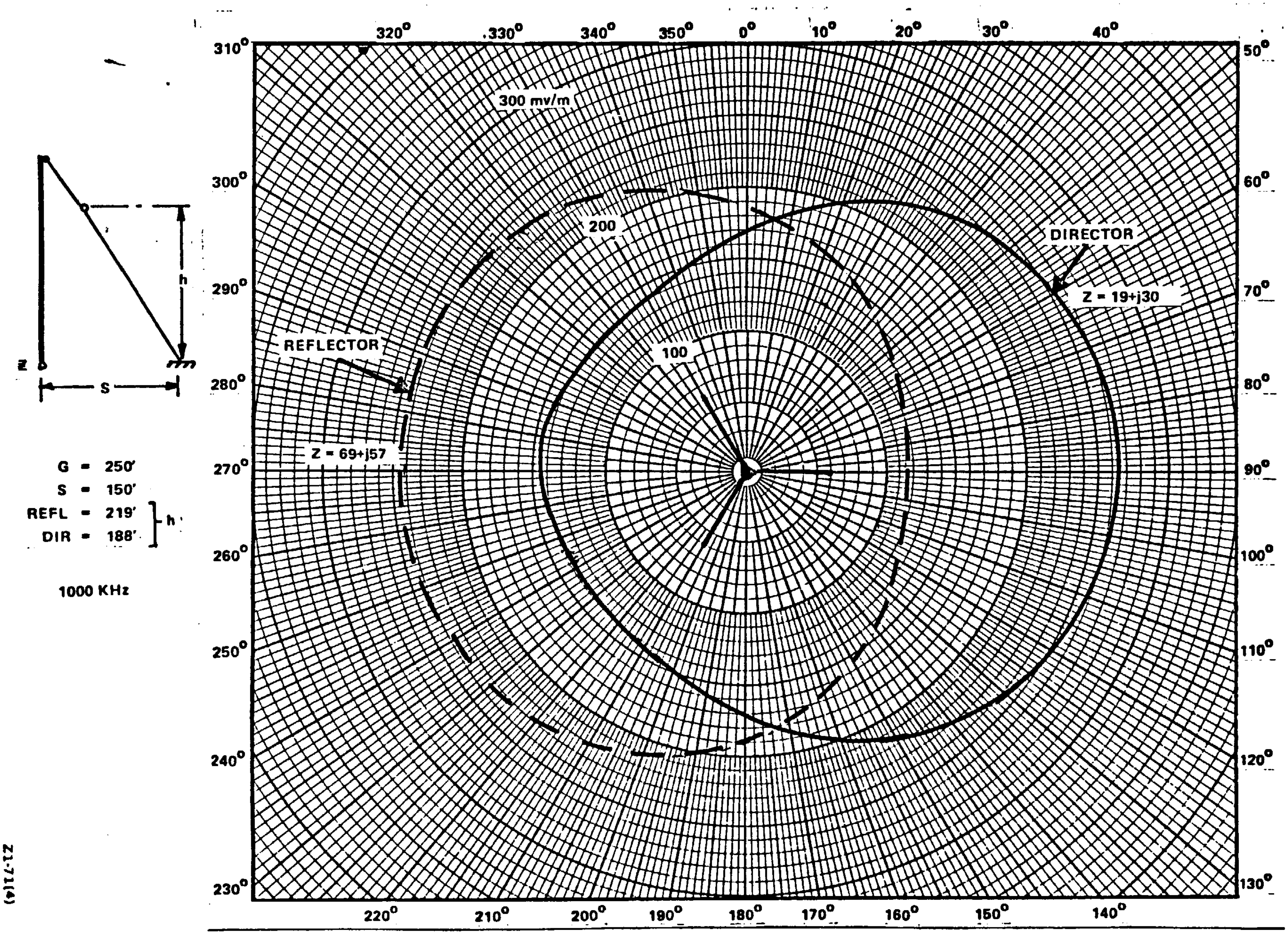
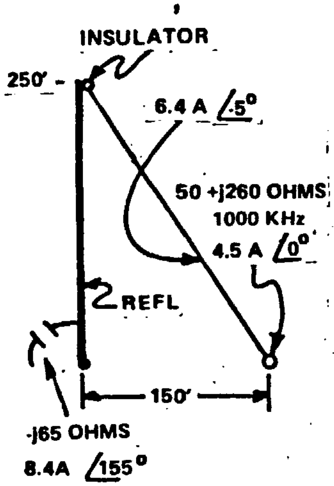


Figure 1 One KW Field At One Mile



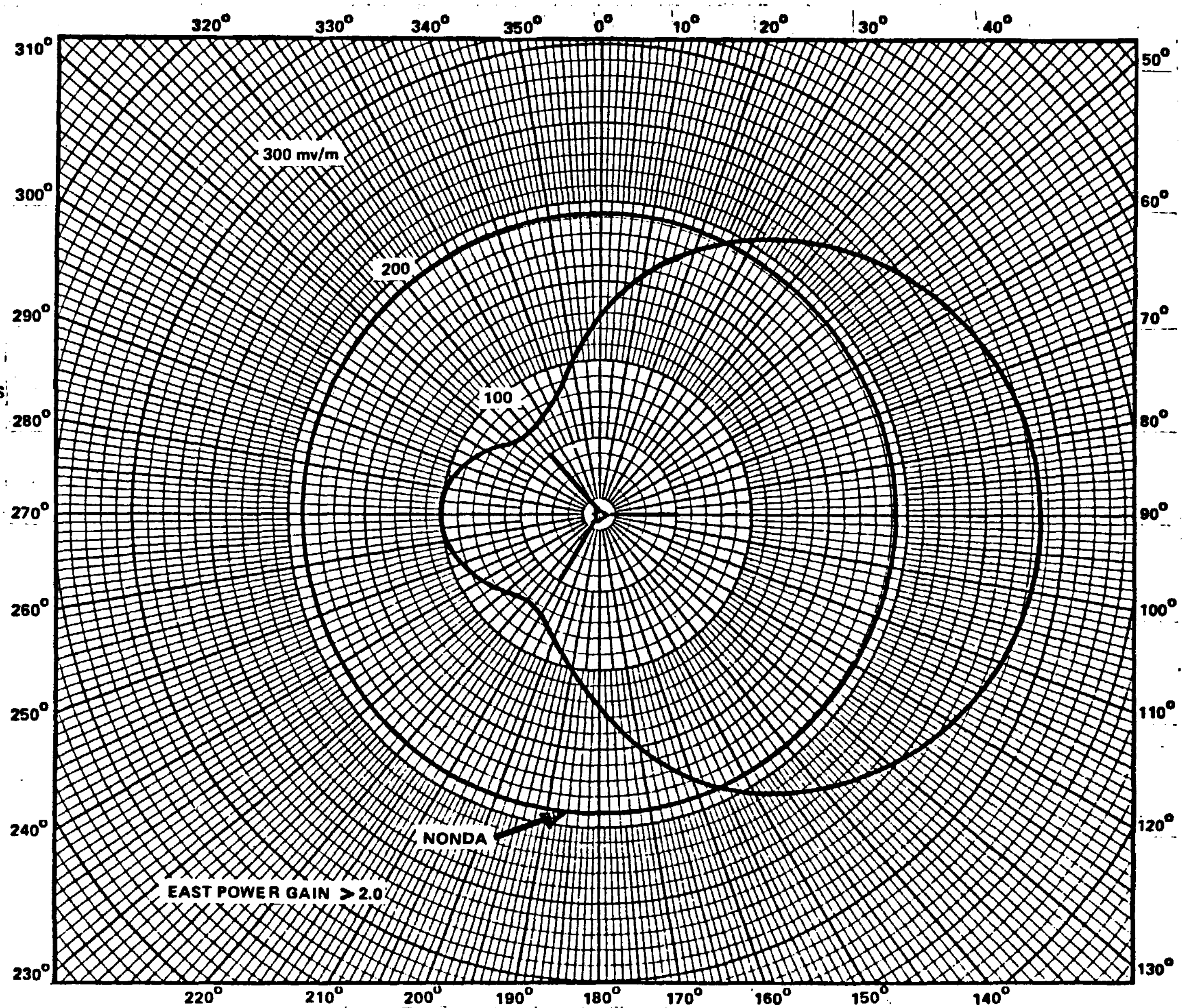
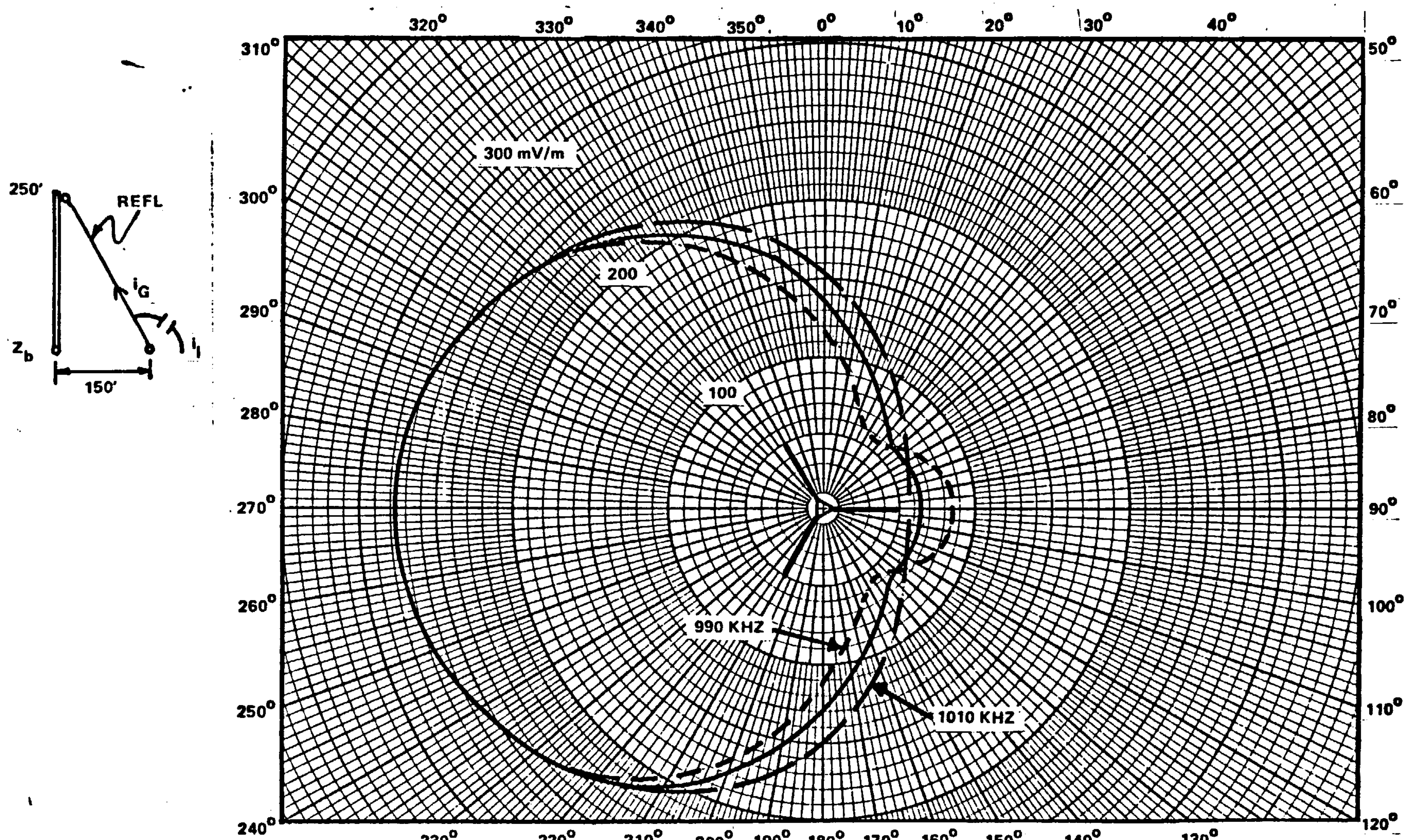


Figure 2 One KW Field At One Mile

Z1-71(1)



KHZ	Z_b	Z_l	i_b	i_l	i_G
990	26.8 +j112.6	0-j161.6	6.1∠0°	6.6∠157°	8.0 ∠157°
1000	37.8 +j125.9	0-j160	5.1∠0°	6.0∠150°	7.3∠150°
1010	54.5 +j137.3	0-j158.4	4.3∠0°	5.3∠140°	6.4 ∠140°

Figure 3 One KW Field At One Mile

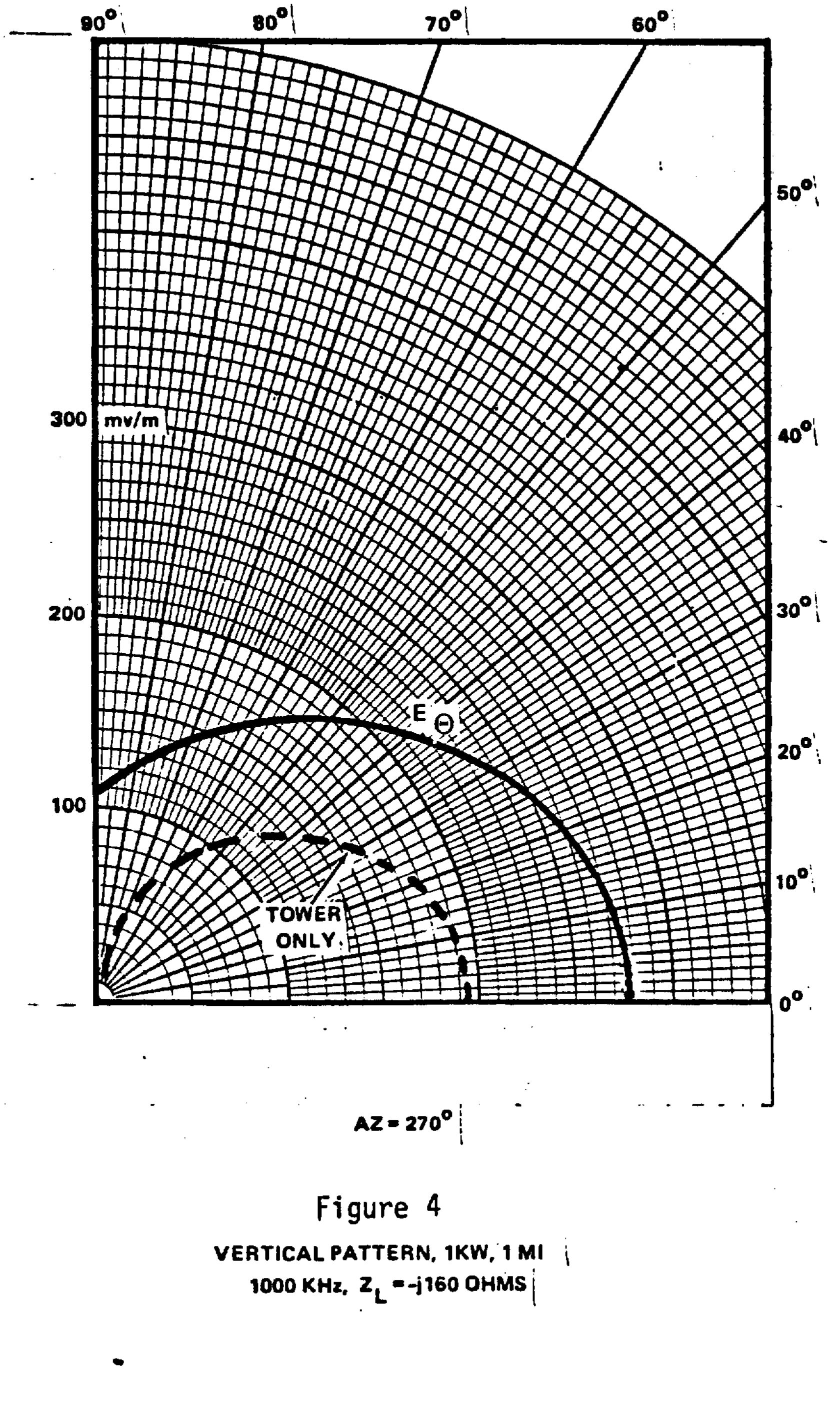


Figure 4

VERTICAL PATTERN, 1KW, 1 MI
1000 KHz, Z_L = -j160 OHMS

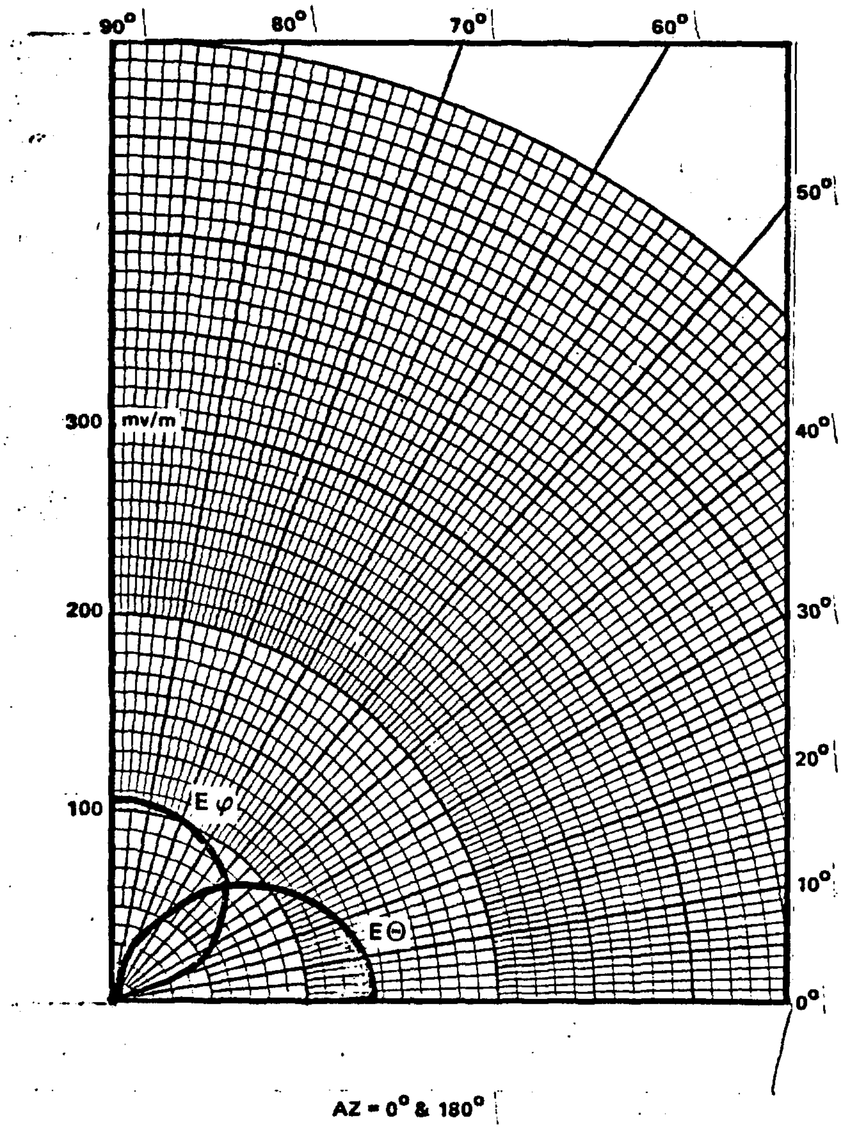


Figure 5

VERTICAL PATTERN, 1KW, 1 MI
1000 KHz, Z_L = -j160 OHMS

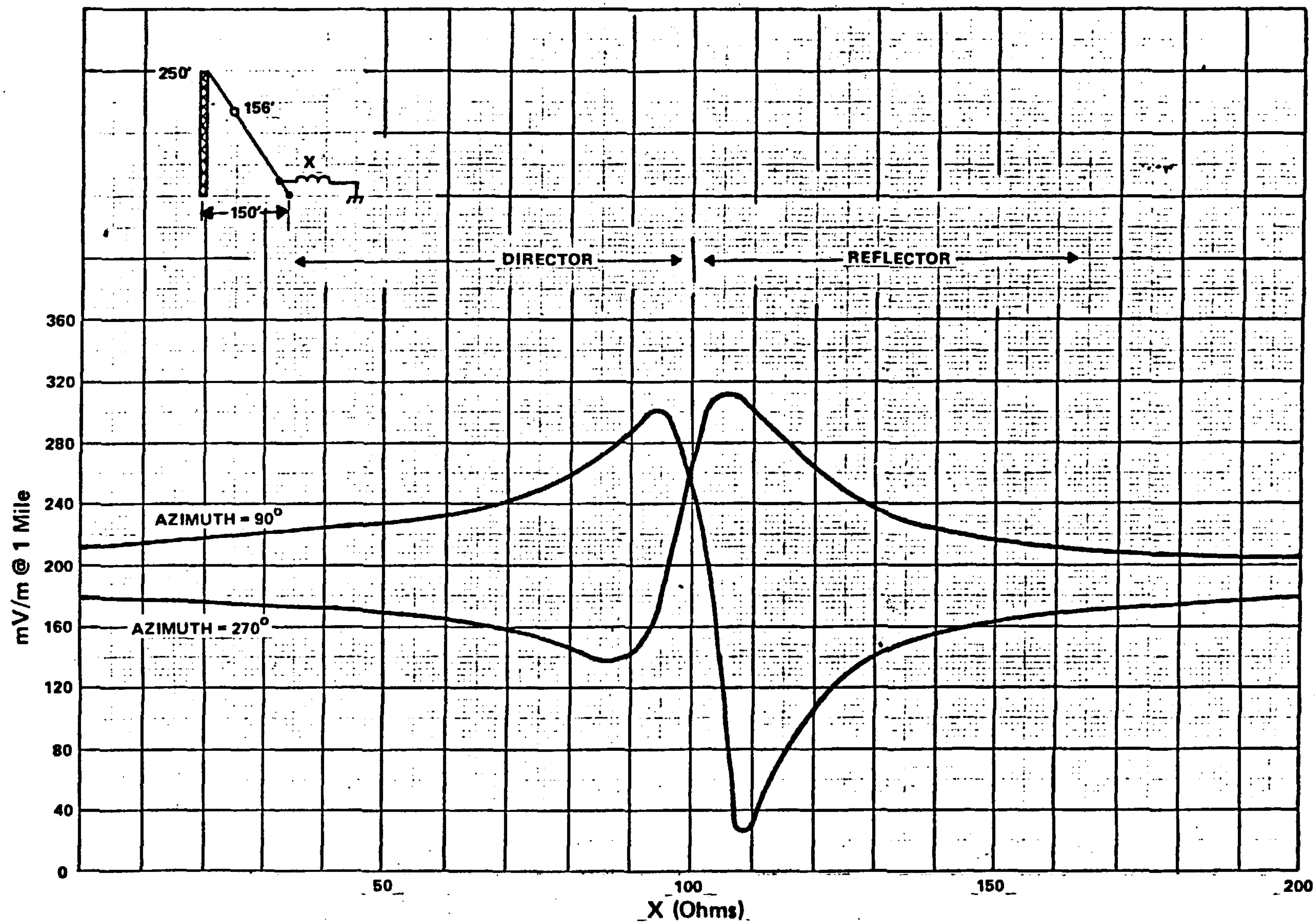


Figure 6 Field Intensity VS Tuning Reactance, 1000 KHz, 1kW

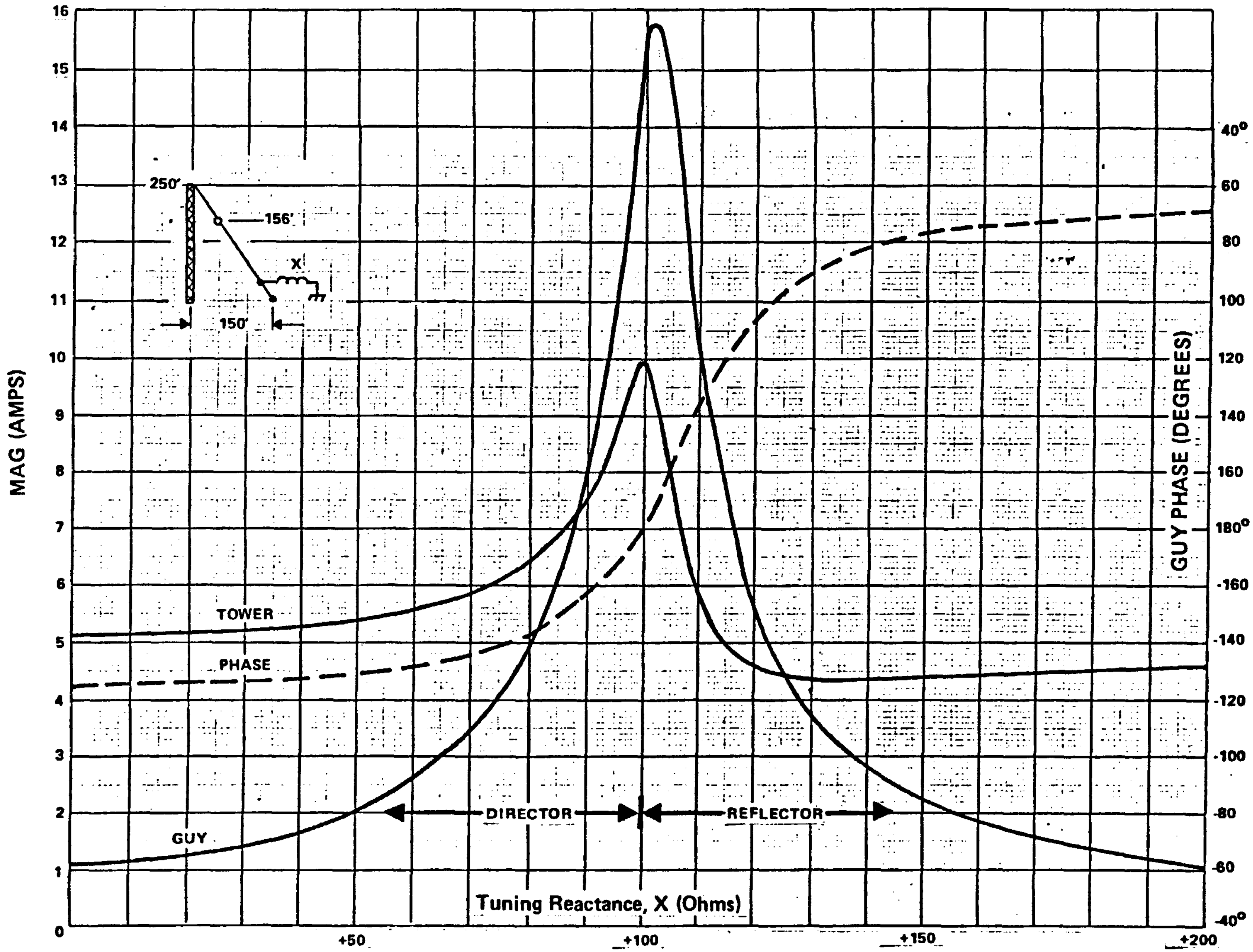


Figure 7. Base Currents VS Tuning Reactance, 1000 KHz, 1kW

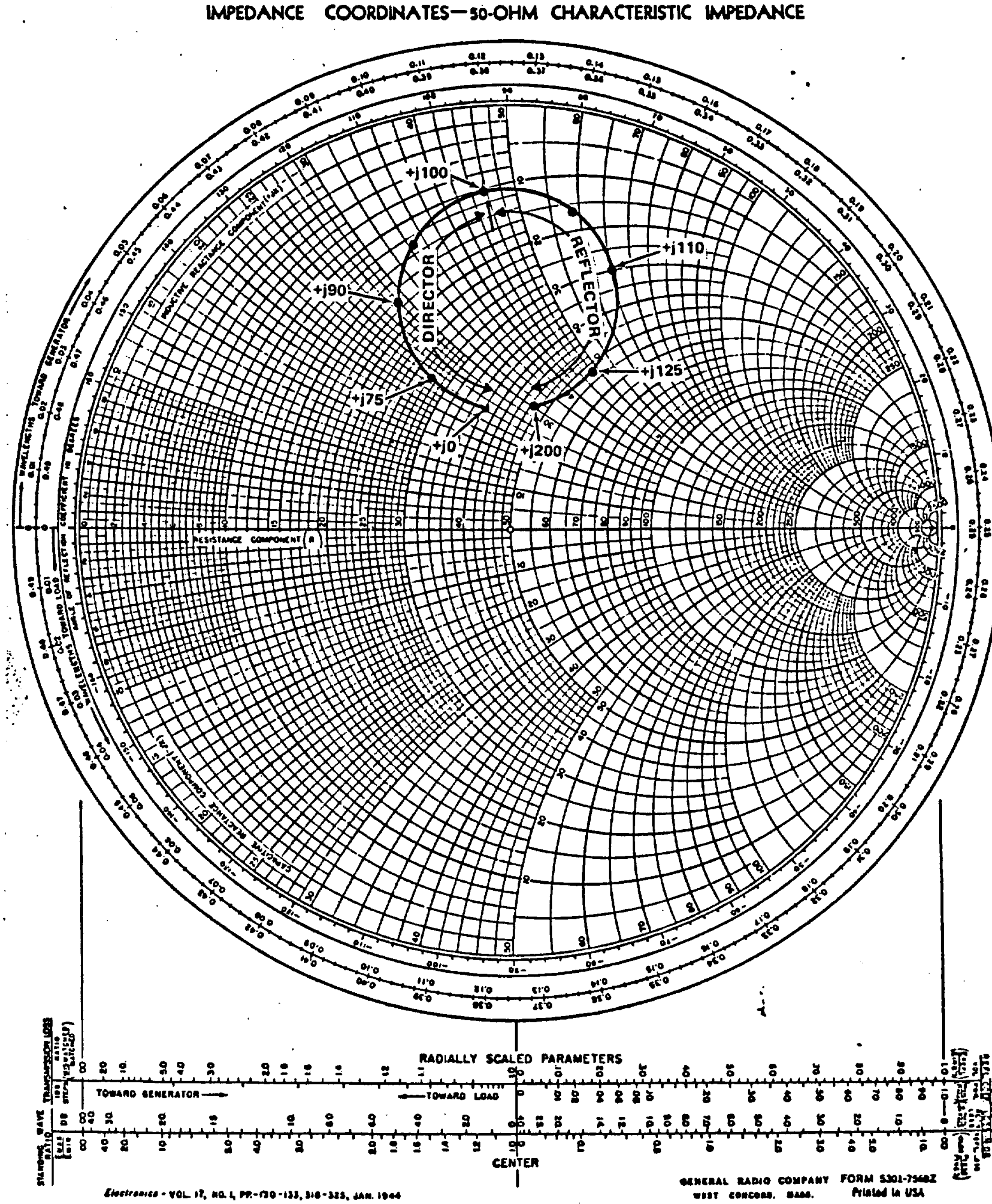


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Figure 8 Tower BAse Z VS Tuning Reactance, 1000 KHz

RADIATION FROM GROUNDED SLANT ANTENNAS

6-30-51

Introduction

Occasionally problems arise involving radiation from other than grounded vertical antennas in the median frequency range. It is proposed in this report to develop the general radiation formulae for a slant antenna over a perfectly conducting earth assuming a sinusoidal current distribution.

Development of Formulae

The orientation of Figure 1 will be used for the derivation of the generalized formulae for radiation from a slant anter

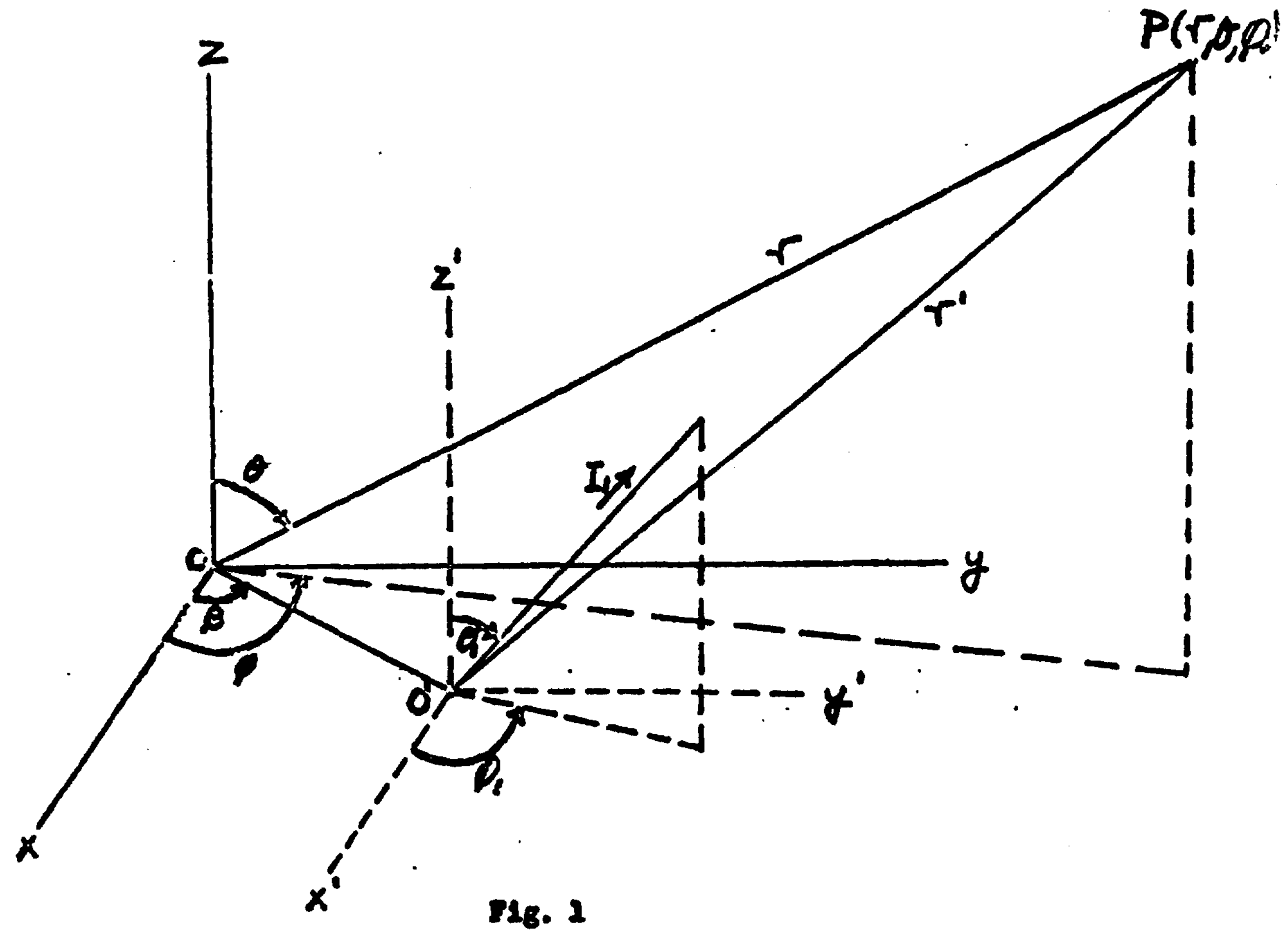

Fig. 1

The x - y plane is ground, and located at point O' is the antenna inclined in the (θ_1, φ_1) direction, using standard spherical coordinates. For the time being the image of this antenna will be ignored.

The general equation for the vector potential associated with the point $P(r,\theta,\varphi)$ is given by:

$$(1) \quad A_1 = \frac{e^{-jkr'}}{4\pi r'} \int_0^{\ell} I_1 e^{jks\cos\xi_1} ds$$

where s is the distance from O' along the antenna, ℓ is the length of the antenna, r' is the distance from O' to P, I_1 is the antenna current, and δ_1 is the angle between the current direction and $O'P$. Assuming the sinusoidal distribution

$$(2) \quad I_1 = I_m \sin k(\ell - s)$$

the vector potential becomes

$$(3) \quad A_1 = \frac{I_m e^{-jkr'}}{4\pi r'} \left\{ \frac{e^{jk\ell\cos\delta_1} - \cos k\ell - j\sin k\ell\cos\delta_1}{k\sin^2\delta_1} \right\}$$

where

$$(4) \begin{cases} r' = \sqrt{(x - s\cos\beta)^2 + (y - s\sin\beta)^2 + z^2} \\ \cos\delta_1 = \sin\theta_1 \sin\theta' \cos(\phi' - \phi_1) + \cos\theta_1 \cos\theta' \end{cases}$$

The primed coordinates are measured from O'.

At great distances

$$(5) \begin{cases} r' \cong r - s\sin\theta\cos(\phi - \beta) \\ \cos\delta_1 \cong \sin\theta_1 \sin\theta \cos(\phi - \phi_1) + \cos\theta_1 \cos\theta \\ A_1 \cong \dfrac{I_m e^{-jk[r - s\sin\theta\cos(\phi-\beta)]}}{4\pi r} \left\{ \dfrac{e^{jk\ell\cos\delta_1} - \cos k\ell - j\sin k\ell\cos\delta_1}{k\sin^2\delta_1} \right\} \end{cases}$$

The image of the antenna in Fig. 1 is shown in Fig. 2. It is noted that, in order to meet the assumed boundary conditions of a perfectly conducting x - y ground plane, the vertical component of the image current is in the same direction as the vertical component of the antenna current in Fig. 1, but the horizontal current components of the antenna and its image are in opposite directions. The vector potential for the image antenna is then given by

$$(6) \begin{cases} A_2 = \dfrac{e^{-jkr'}}{4\pi r'} \displaystyle\int_{\ell}^{0} I_2 e^{-jks'\cos\delta_2} \, ds' \\ I_2 = I_m \sin k(\ell + s) \end{cases}$$

where s' is the distance from O' along the direction of the image current and δ_2 is the angle between the image current and $O'P$. Thus,

$$(7)\begin{cases} A_2 = \dfrac{I_m e^{-jkr'}}{r'} \left\{ \dfrac{e^{-jkl\cos\delta_2} - \cos kl + j\sin kl\cos\delta_2}{k\sin^2\delta_2} \right\} \\ \cos\delta_2 = -\sin\theta_1 \sin\theta' \cos(\phi' - \phi_1) + \cos\theta_1 \cos\theta' \end{cases}$$

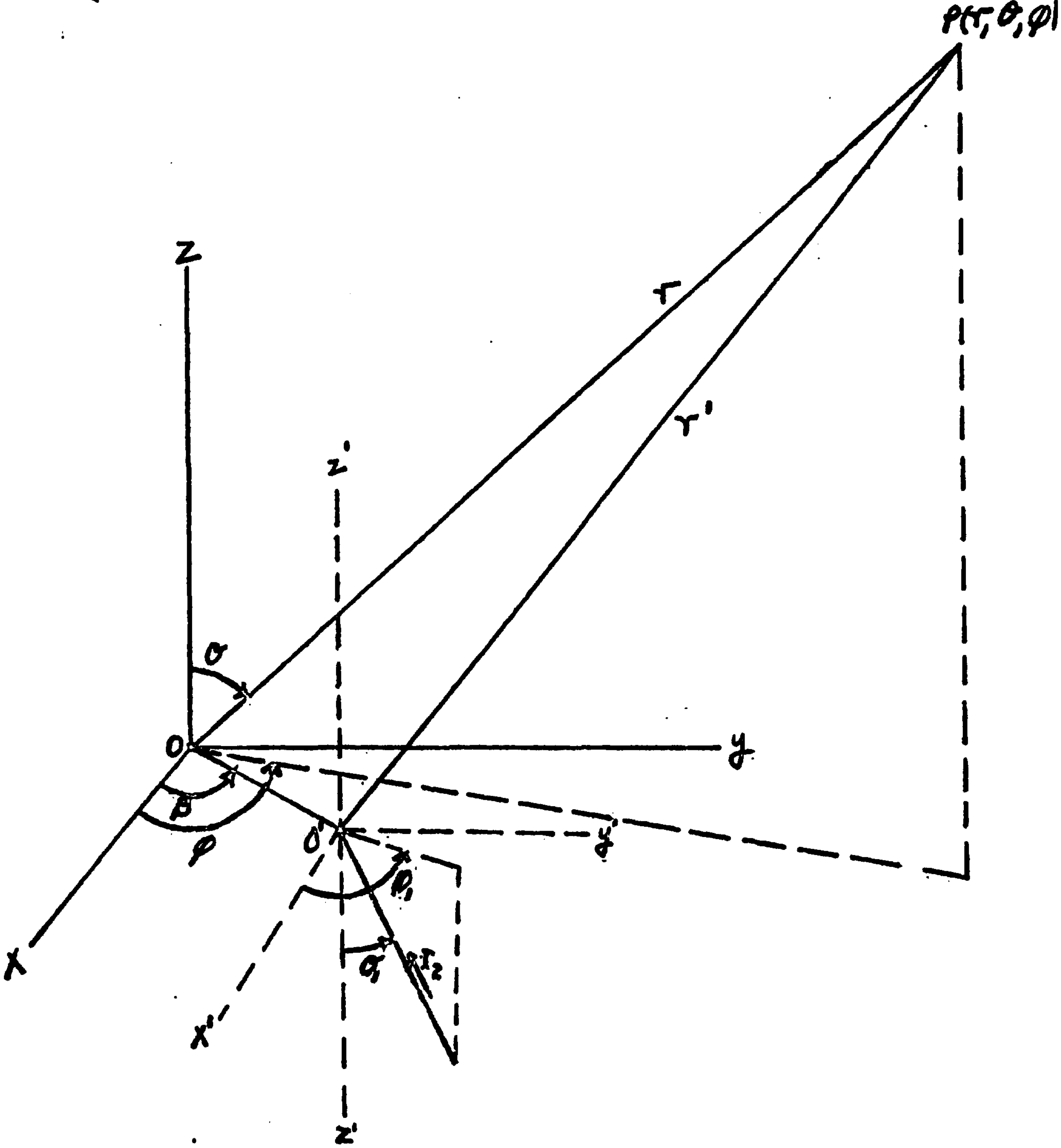

Fig. 2

At great distances

$$(8)\quad \begin{cases} A_2 \cong \dfrac{I_m e^{-jk[r - s\sin\theta\cos(\varphi-\beta)]}}{4\pi r}\left\{\dfrac{e^{-jkh\cos\delta_2} - \cos kh - j\sin kh\cos\delta_2}{k\sin^2\delta_2}\right\} \\ \cos\delta_2 \cong -\sin\theta_1\sin\theta\cos(\varphi-\varphi_1) + \cos\theta\cos\theta_1 \end{cases}$$

The resultant vector potential A is found by adding vectorally A_1 and A_2 which have the same directions as their respective activating currents I_1 and I_2. The resultant E_δ vector will then be given by

$$(9)\quad E_\delta = j\omega\mu A\sin\delta$$

where δ is the angle between the resultant A vector and O P. The E_δ vector is in the plane of A and O P and is perpendicular to O P, being positive in the direction of increasing δ.

The field intensity at P is probably best calculated numerically by projecting the resultant vector potential A into vertical and horizontal components. Thus,

$$(10)\quad \begin{cases} A_z = (A_1 + A_2)\cos\theta_1 \\ A_H = (A_1 - A_2)\sin\theta_1 \end{cases}$$

The E_θ and E_φ field intensities are then given by

$$(11)\quad \begin{cases} E_\theta = j\omega\mu[A_z\sin\theta - A_H\cos\theta\cos(\varphi-\varphi_1)] \\ E_\varphi = -j\omega\mu A_H\sin(\varphi-\varphi_1) \end{cases}$$

In terms of horizontally and vertically polarized fields, E_H and E_V, respectively, the following identities are recognized:

$$(12)\quad \begin{cases} E_V = -E_\theta \\ E_H = -E_\varphi \end{cases}$$

It is interesting to note from (5) and (8) that displacement of the antenna from the origin has only the effect of introducing a phase shift,

$k S\sin\theta\cos(\varphi-\beta)$. It is also noted from (9) that the vector potential is zero in the direction of the activating current - i. e. A_1 or A_2 are zero when δ_1, or δ_2 are zero, respectively.